National Climatic Data Center

DATA DOCUMENTATION

FOR

DATA SET 9100 (DSI-9100)
Global Historical Climatology Network

December 16, 2002

National Climatic Data Center
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Table of Contents

1.   Abstract: The Global Historical Climatology Network Version 2 temperature database was released in May 1997. This century-scale data set consists of monthly surface observations from ~7,000 stations from around the world. This archive breaks considerable new ground in the field of global climate databases. The enhancements include: (1) data for additional stations to improve regional-scale analyses, particularly in previously data-sparse areas; (2) the addition of maximum/minimum temperature data, to provide climate information not available in mean temperature data alone; (3) detailed assessments of data quality to increase the confidence in research results; (4) rigorous and objective homogeneity adjustments to decrease the effect of non-climatic factors on the time series; (5) detailed metadata (e.g., population, vegetation, topography) that allows more detailed analyses to be conducted; and (6) an infrastructure for updating the archive at regular intervals, so that current climatic conditions can constantly be put into historical perspective. This paper, and the sites below, describes these enhancements in detail.

http://www1.ncdc.noaa.gov/pub/data/papers/1997tp12b.pdf

http://www.ncdc.noaa.gov/oa/climate/ghcn/ghcn.SELECT.html

Man has long been fascinated by the weather. Instruments that could reliably measure air temperature had been developed by the late 17th century. Renowned for his manufacture of precision meteorological instruments, Daniel Gabriel Fahrenheit invented the mercury thermometer in 1714. Soon, individuals and organizations began to establish networks of meteorological instruments to help quantify and record the weather. There were many reasons to do this, ranging from agriculture to forecasting. The first large-scale monitoring efforts were in Europe and the United States. Over time, the implementation of these instruments diffused into the rest of the world. Currently, most politically stable countries operate large networks of weather observing stations.

Today, climate research relies heavily on the records from instruments at these near-surface weather stations. There are two reasons for this reliance: instrumental records represent direct samples at exact points in space and time, and they have been collected at over 100,000 locations in the past two centuries (F. Wernstedt, pers. comm. 1994). While other indicators (e.g., tree rings) also record climate variations, they generally are inferential rather than direct measurements of meteorological conditions and are currently available at far fewer locations than their instrumental counterparts. Thus it is the "instrumental network" that constitutes the most spatially and temporally complete record of land surface climate since the onset of the Industrial Revolution (Jones 1994). Unfortunately, not all available historic data have been digitized. In the digital archives, there are many more station years of monthly data available than daily data with correspondingly much better spatial coverage.

Because most instrumental networks were established to monitor local weather and not the long-term climate, there are practical problems in using these data to study climate change. For instance, the records are often not digitized and/or are not readily available outside of the country in which they were measured. An uneven distribution of stations introduces network biases which have significant effects on estimated temperature trends, particularly at the regional scale. Instrumental records also often contain data errors resultant from the data recording and archiving processes. These

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errors, which take many forms (e.g., outliers, truncations), reduce confidence in the analyses. In addition, instrumental records are subject to inhomogeneities caused by many factors, such as local station moves and the introduction of new thermometers. Such inhomogeneities introduce non-climatic variation into historical records and thus further cloud temporal trends. In short, each of these forces contributes to a bias embedded in the historical record that complicates the detection of climatic change on any scale.

Many efforts to produce long-term monthly global climate databases have addressed these issues, though most emphasized data collection. One of the first and longest running efforts is the World Weather Records (WWR) initiative, which commenced in 1923 and has resulted in the regular publication of decadal series of global climate records ever since (Clayton 1927). Another fine example is the National Center for Atmospheric Research's annually published World Monthly Surface Station Climatology data set (WMSSC, Spangler and Jenne 1992), which consists of WWR, miscellaneous acquisitions, and the National Climatic Data Center's (NCDC) Monthly Climatic Data for the World for more recent records. Both the WWR and WMSSC are outstanding databases in their own right; however, owing to simple time, resource, and mission constraints, these sets (and others of their kind) have not yet integrated some newly available data sets (e.g., data from U.S.-Russia bilateral exchanges). Furthermore, neither database contains detailed station homogeneity assessments, limiting their utility in studies of climate change. This issue has been more commonly addressed to some degree by individual researchers who compiled their own global and hemispheric data sets for specific applications. The most famous of these is the data set of Jones (1986, 1994), which has been used extensively in climate research.

In the early 1990s, climatologists from NCDC and the Carbon Dioxide Information Analysis Center (CDIAC) undertook a new initiative aimed at creating a data set appropriate for the study of climate change at both global and regional scales. Building upon the fine efforts of its predecessors, this database, known as the Global Historical Climatology Network (GHCN), was released in 1992 (Vose et al. 1992). It contains quality-controlled monthly climatic time series from 6039 land-based temperature stations worldwide. Compared to most data sets of this type (e.g., Jones 1994), this initial release of GHCN was larger and had more detailed spatial coverage. Since its creation, thousands of copies have been provided free of charge to researchers, educators, and students around the world, and requests for both the basic data set and derived products (e.g., gridded temperature anomalies) currently average over 200 per month from NCDC and CDIAC. More importantly, it has become a popular tool in climate change research (e.g., Brown et al. 1993; Young 1993; Groisman et al. 1994a, 1994b; Karl et al. 1994; Quereda and Monton 1994, 1995; Balling 1995; Baranyi and Ludmany 1995; Epperson et al. 1995; Gutzler, 1996; Adkison et al. 1996; Tayanc et al. 1997).

Given the popularity of GHCN, researchers at NCDC, CDIAC, and Arizona State University have prepared an enhanced database to serve the ever-increasing demand for these data. This archive, GHCN version 2, breaks considerable new ground in the field of global climate databases. Enhancements include: (1) data for additional stations to improve regional- scale analyses, particularly in previously data sparse areas; (2) the addition of maximum/minimum temperature data, to provide climate information not available in mean temperature data alone; (3) detailed assessments of data quality to increase the confidence in research results; (4) rigorous and objective homogeneity adjustments to decrease the effect of non-climatic factors on the time series; (5) detailed metadata (e.g., population, vegetation, topography) that allows
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more detailed analyses to be conducted; and (6) an infrastructure for updating the archive at regular intervals, so that current climatic conditions can constantly be put into historical perspective. This paper describes these enhancements in detail.
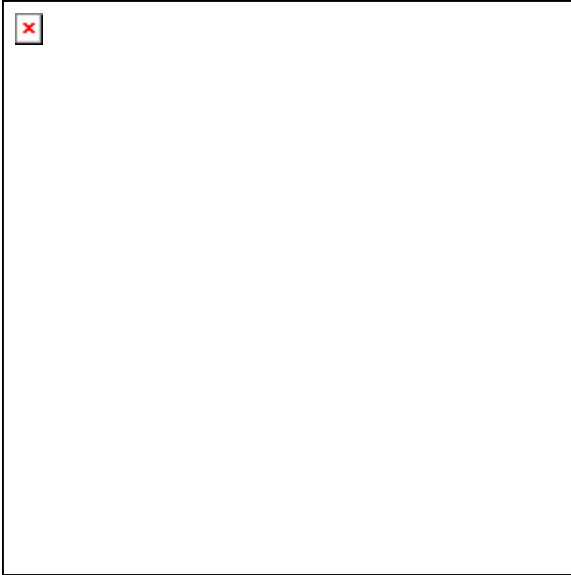
Figures

Note: Click on the figures below to see larger versions.

[Figure 1](#):

Tombouctou, Mali mean temperature data for May from 1950 to 1995. Mean temperature data for Tombouctou were present in six of GHCN's 31 source data sets, with data starting in 1897. Of the six time series, several of these could be combined leaving four different Tombouctou mean temperature time series (duplicates). In the graph, each duplicate is indicated by a different symbol. Many of the data points are exactly the same, but the differences between the duplicates were significant enough that the time series could not be combined. The reason why GHCN mean temperature data have duplicates while mean maximum and minimum temperature data do not is because there are over 100 different ways in which daily mean temperature has been calculated by meteorologists.

[Figure 2a](#)

[Figure 2b](#).

Time series of:

[(a) the number of stations](#)
[(b) the number of 5x5 degree boxes](#)

for mean temperature (solid) and maximum and minimum temperature (dashed). The graphs start in 1850, but the earliest mean temperature datum is for January 1701 from Berlin, Germany and the earliest mean maximum and minimum temperature data in GHCN are for March 1840 from Toronto, Canada. The reasons why the number of stations in GHCN drop off in recent years are because some of GHCN's source data sets are retroactive data compilations (e.g., World Weather Records) and other data sources were created or exchanged years ago. Only three data sources are available in near real time. The rise in maximum and minimum temperature stations and grid boxes in 1995 and 1996 is due to

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the World Meteorological Organization's initiation of international exchange of monthly CLIMAT maximum and minimum temperature data over the Global Telecommunications System in November 1994.

[Figure 3a](#)
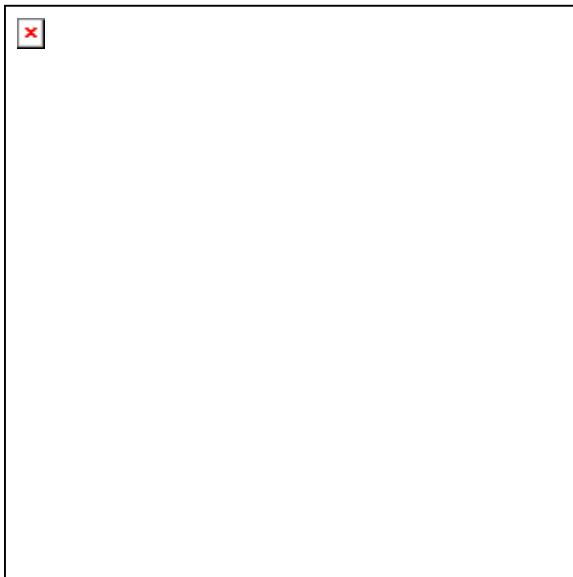
[Figure 3b](#).

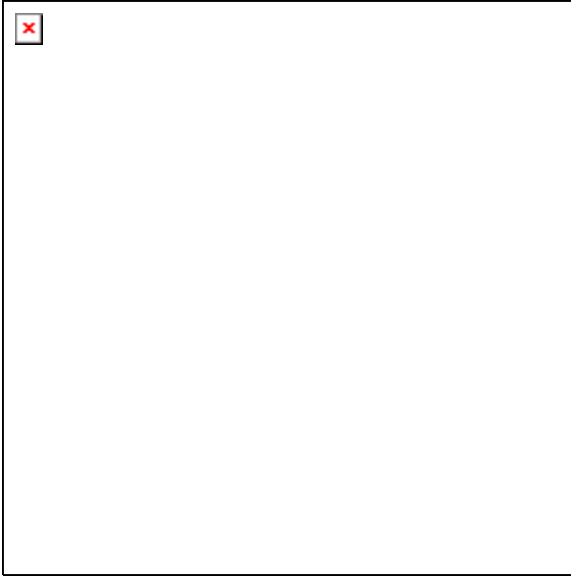Maps of GHCN mean temperature station locations:

[(a) all GHCN mean temperature stations](#)
[(b) mean temperature stations with data in 1900](#).

Approximately 1,000 GHCN stations have a century or more of mean temperature data. Work is underway to fill in some of the large data sparse regions shown in 3b by digitizing selected station data from colonial era archives (Peterson and Griffiths, 1996).

[Figure 4a](#)

[Figure 4b](#).

Maps of GHCN maximum and minimum temperature station locations:

[(a) all GHCN maximum and minimum temperature stations](#)
[(b) GHCN temperature stations with maximum and minimum data in 1900](#).

Because mean monthly maximum and minimum temperature have not been regularly exchanged until recently there are large gaps in GHCN's maximum and minimum temperature coverage. These gaps will be slowly filled with the incorporation of new sources of data.
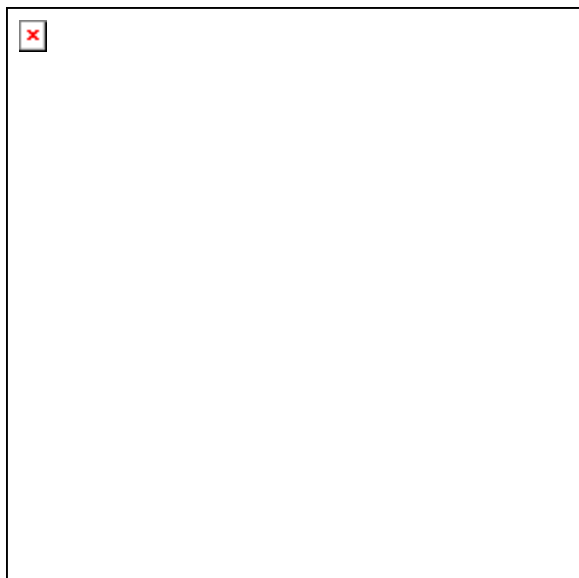
[Figure 5](#).

GHCN mean temperature stations that can be regularly updated. Many of these stations will be updated with maximum and minimum temperature data as well. The three sources of data for updating are the U.S. Historical Climatology Network, a subset of the U.S. First Order stations, and monthly CLIMAT reports transmitted over the Global Telecommunications System.

2.   Element Names and Definitions:
There are 3 raw temperature datasets (monthly maximum, monthly minimum, and monthly mean) and 3 adjusted datasets. Each of the 3 datasets has a corresponding station inventory file. There is also one country code file containing a 3 digit id for each country in this dataset.

The three raw data files are:

        v2.mean
        v2.max
        v2.min

The versions of these data sets that have data which were adjusted to account for various non-climatic inhomogeneities are:

        v2.mean.adj
        v2.max.adj
        v2.min.adj

Element Names and Definitions for Data Files

Station number is comprised of 3 parts.

        CTRY   : country code (3 digits)
        NWMO   : nearest WMO station number (5 digits)
        MODF   : modifier (3 digits) (this is usually 000 if it is that WMO
        station)

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DUPL     : Duplicate number.  One digit (0-9).  The duplicate order is
             based on length of data.  Maximum and minimum temperature
             files have duplicate numbers but only one time series (because
             there is only one way to calculate the mean monthly maximum
             temperature).  The duplicate numbers in max/min refer back to
             the mean temperature duplicate time series created by
             (Max+Min)/2.

YEAR     : Four digit year

DATA(12) : 12 monthly values each as a 5 digit integer.  To
             convert to degrees Celsius they must be divided by 10.
        Missing monthly values are given as -9999.
```

If there are no data available for that station for a year, that year is not
included in the data base.

Element Names and Definitions for Inventory File

```
IC     : 3 digit country code; the first digit represents WMO
           region/continent
IWMO   : 5 digit WMO station number
IMOD   : 3 digit modifier; 000 means the station is probably the WMO
           station; 001, etc. mean the station is near that WMO station
NAME   : 30 character station name
RLAT   : latitude in degrees.hundredths of degrees, negative =
           South of Equator.
RLON   : longitude in degrees.hundredths of degrees, - = West
IELEVS: station elevation in meters, missing is -999
IELEVG: station elevation interpolated from TerrainBase gridded
           data set
POP    : 1 character population assessment:
             R = rural (not associated with a town of >10,000
                 population)
             S = associated with a small town (10,000-50,000)
             U = associated with an urban area (>50,000)
IPOP   : population of the small town or urban area (needs to be
           multiplied by 1,000).  If rural, no analysis:  -9.
TOPO   : general topography around the station:
             FL = flat
             HI = hilly
             MT = mountain top
             MV = mountainous valley or at least not on the top
                  of a mountain.
STVEG : general vegetation near the station based on Operational
           Navigation Charts;
             MA = marsh
             FO = forested
             IC = ice
             DE = desert
             CL = clear or open
```

NOTE: not all stations have this information in which case: xx.

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STLOC : station location based on 3 specific criteria:
             IS = Is the station on an island smaller than 100 km**2 or
                  narrower than 10 km in width at the point of the station?
:
:                                    10:
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              CO = Is the station is within 30 km from the coast?
              LA = Is the station is next to a large (> 25 km**2) lake?

Note:  A station may be all three but only labeled with one with
        the priority IS, CO, then LA.  If none of the above: no.

        ILOC  : if the station is CO, iloc is the distance in km to the
                 coast. If station is not coastal:  -9.

        AIRSTN: A if the station is at an airport; otherwise x

        ITOWNDIS: the distance in km from the airport to its associated small
        town or urban center (not relevant for rural airports or non airport
        stations in which case: -9)

        GRVEG: gridded vegetation for the 0.5x0.5 degree grid point closest to
        the station from a gridded vegetation data base. 16 characters.
```

Element Names and Definitions for Country Codes File.

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        CTRYCOD : 3-digit country code
        CTRYNAME: Name of country
```

Element Names and Definitions

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        CTRY    : As defined for Data file
        NWMO    : As defined for Data file
        MODF    : As defined for Data file
        DUPL    : As defined for Data file
        YEAR    : 4-digit year
        MONTH   : Month of year
        BAD_DATA: Monthly value that failed our Quality Control checks. Written
                  as a 5 digit integer.  Divide by 10 to get the value in
                  degrees Celcius.
```

3.   Start Date: 170101 (Most stations begin no earlier than the late 1800's.)

4.   Stop Date: New monthly data are added to GHCN a few days after the end of
the month. Please note that sometimes these new data are later replaced with
data with different values due to, for example, occasional corrections to the
transmitted data that countries will send over the Global Telecommunications
System.

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        V2. Mean: Dec 1996 Some U.S. stations through Dec 1977
        V2. Max : Dec 1996 Some U.S. stations through Dec 1977
        V2. Min : Dec 1996 Some U.S. stations through Dec 1977
```

5.   Coverage: Global

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        a.  Southernmost Latitude:  90S
        b.  Northernmost Latitude:  90N
        c.  Westernmost Longitude: 180W
        d.  Easternmost Longitude: 180E
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6. How to Order Data:

Ask NCDC's Climate Services about the cost of obtaining this data set.
Phone: 828-271-4800
FAX: 828-271-4876
E-mail: **NCDC.Orders@noaa.gov**

7. Archiving Data Center:

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, NC 28801-5001
Phone: (828) 271-4800.

8. Technical Contact:

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, NC 28801-5001
Phone: (828) 271-4800.

9. Known Uncorrected Problems: None.

10. Quality Statement: GHCN Quality Control (QC) is a three-stage process. A full description of GHCN QC tests and their justification is given in Peterson et al. (1997), so the following is a short summary of the QC applied to GHCN.

The first stage examines the quality and appropriateness of the source data sets. Thirty-one source data sets contributed temperature data to GHCN while several additional potential sources had to be rejected. The rejections were primarily caused by (a) homogeneity adjusted data without access to original observations, (b) the monthly data were derived from synoptic reports which are almost always incomplete thereby causing unacceptable errors or biases, and (c) significant processing errors that indicated the source data set was unreliable.

The second stage examined individual station time series. These tests included comparing the stations to gridded climatology (Legates and Willmott 1990) and plotting the stations on Operational Navigation Charts (see section 7 on metadata). Both of these processes uncovered mislocated stations and the former uncovered stations that were digitized 6 months out of phase. Additionally, we tested each time series for significant discontinuities using the Cumulative Sum test (CUSUM, van Dobben de Bruyn 1968) which looks for changes in the mean. We also developed a test, called SCUSUM, to look for changes in the variance or scale. Finally we looked for runs of three or more months of the same value in the time series.

The third and final stage of GHCN QC evaluated individual data points to determine if they were outliers in time and space. All data points that were determined to be greater than 2.5 biweight standard deviations (Lanzante 1996) from the time series mean were flagged. Each of these flagged data points were then compared to neighboring stations to determine if the extreme value represented an extreme climate event in the region. Over 85% of the previously
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flagged data points were determined to be valid using the spatial QC test. Those data points that failed both of these tests were removed from the main GHCN data file but included in a separate file for possible use by researchers possessing additional, potentially corroborating information.

Duplicate Elimination

A time series for a given station can frequently be obtained from more than one source. For example, data for Tombouctou, Mali were available in six different source data sets. When "merging" data from multiple sources, it is important to identify these duplicate time series because: (1) the inclusion of multiple versions of the same station creates biases in areally averaged temperature analyses, and (2) the same station may have different periods of record in different data sets, therefore "mingling" the two versions can create longer time series.

The goal of duplicate station elimination is to reduce a large set of n time series (many of which are identical) to a much smaller set of m group of time series that are unique. In the case of maximum and minimum temperature, 8,000 source data set time series were reduced to 4,964 unique time series. This was accomplished in the following fashion. First, the data for every station were compared with the data for every other station. This naturally started with stations whose metadata indicated they were in approximately the same location. Similarity was assessed by computing the total number of months of identical data as well as the percentage of months of identical data. Maximum/minimum temperature time series were considered duplicates of the same station if they shared the same monthly value at least 90% of the time with at least 12 months of data being identical and no more than 12 being different. This process identified the duplicates which were then mingled to form time series with longer periods of record after a manual inspection of the metadata (to avoid misconcatenations). This process was then repeated on the mingled data set without the initial metadata considerations so every time series was compared to all the other time series in the database. Similarity of time series in this step was judged by computing the length of the longest run of identical values.

Cases where the time series were determined to be duplicates of the same station but the metadata indicated they were not the same station were examined carefully and a subjective decision was made. This assessment provided additional Quality Control of station locations and the integrity of their data. For example, a mean temperature time series for Thamud, Yemen had 25 years (1956-1981) of monthly values that were exactly identical to the mean temperature data from Kuwait International Airport (12 degrees farther north). Needless to say, one of these time series was in error. As with most of these problems, determining which time series was erroneous was fairly easy given the data, metadata, knowledge about the individual data sources, duplicate data, and other climatological information available.

The procedure for duplicate elimination with mean temperature was more complex. The first 10,000 duplicates (out of 30,000+ source time series) were identified using the same methods applied to the maximum and minimum temperature data sets. Unfortunately, because monthly mean temperature has been computed at least 101 different ways (Griffiths 1997), digital comparisons could not be used to identify the remaining duplicates. Indeed, the differences between two different methods of calculating mean temperature at a particular station can be greater than the temperature difference from two neighboring stations. Therefore, an intense scrutiny of associated
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metadata was conducted. Probable duplicates were assigned the same station number but, unlike the previous cases, not mingled because the actual data were not exactly identical (although they were quite similar). As a result, the GHCN version 2 mean temperature data set contains multiple versions of many stations. For the Tombouctou example, the 6 source time series were merged to create 4 different but similar time series for the same station (see Figure 1).

Preserving the multiple duplicates provides some distinct benefits. It guarantees no concatenation errors. Adding the recent data from one time series to the end of a different time series can cause discontinuities unless the mean temperature was calculated the same way for both time series. It also preserves all possible information for the station. When two different values are given for the same station/year/month it is often impossible for the data set compiler to determine which is correct. Indeed, both may be correct given the different methods used to calculate mean temperature.

Unfortunately, preserving the duplicates may cause some difficulty for users familiar with only one "correct" mean monthly temperature value at a station. There are many different ways to use data from duplicates. All have advantages and disadvantages. One can use the single duplicate with the most data for the period of interest; use the longest time series and fill in missing points using the duplicates; average all data points for that station/year/month to create a mean time series; or combine the information in more complicated ways, such as averaging the first difference ($FD_{year\ 1} = T_{year\ 2} - T_{year\ 1}$) time series of the duplicates and creating a new time series from the average first difference series. Which technique is the best depends on the type of analysis being performed.

11. <u>Essential Companion Datasets</u>: None.

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